CLAIMS

1. A method of learning user query concept for searching visual images encoded in computer readable storage media comprising:

providing a multiplicity of respective sample images encoded in a computer readable medium;

providing a multiplicity of respective sample expressions encoded in computer readable medium that respectively correspond to respective sample images and in which respective terms of such respective sample expressions represent respective features of corresponding sample images;

defining a user query concept sample space bounded by a boundary k-CNF expression which designates a more specific concept within the user query concept sample space and by a boundary k-DNF expression which designates a more general concept within the user query concept sample space;

refining the user query concept sample space by,

selecting multiple sample images from within the user query concept sample space;

presenting the multiple selected sample images to the user;

soliciting user feedback as to which of the multiple presented sample images are close to the user's query concept;

wherein refining the user query concept sample space further includes, refining the boundary k-CNF expression by,

identifying respective terms of respective sample expressions that contradict corresponding respective disjunctive terms of the boundary k-CNF expression for those respective sample expressions corresponding to respective sample images indicated by the user as close to the user's query concept;

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determining which, if any, respective disjunctive terms of the boundary k-CNF expression identified as contradicting corresponding respective terms of sample expressions indicated by the user as close to the user's query concept to remove from the boundary k-CNF expression;

removing from the boundary k-CNF expression respective disjunctive terms determined to be removed;

wherein refining the user query concept sample space further includes, refining the boundary k-DNF expression by,

identifying respective terms of respective sample expressions that do not contradict corresponding respective conjunctive terms of the boundary k-DNF expression for those respective sample expressions corresponding to respective sample images indicated by the user as not close to the user's query concept;

determining which, if any, respective conjunctive terms of the boundary k-DNF expression identified as not contradicting corresponding respective terms of sample expressions indicated by the user as not close to the user's query concept to remove from the boundary k-DNF expression; and

removing from the boundary k-DNF expression respective conjunctive terms determined to be removed.

2.   The method of claim 1 further including:

removing respective sample images presented to the user from eligibility for presentation to that same user.

3.   The method of claim 1 further including:

repeating the steps involved in refining the user query concept sample space.

4.   The method of claim 1 further including:

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repeating the steps involved in refining the user query concept sample space until the boundary k-DNF expression becomes identical to or more specific than the boundary k-CNF expression.

5.   The method of claim 1 further including:

repeating the steps involved in refining the user query concept sample space until the user ends search.

6.   The method of claim 1 further including:

dividing the boundary k-CNF into multiple sub-group k-CNF expressions by separating respective terms that can express each other's feature information into different sub-group k-CNF expressions such that such separation of terms does not result in loss of combinations of feature information due to such dividing;

wherein identifying respective terms of respective sample expressions that contradict corresponding respective disjunctive terms of the boundary k-CNF expression involves identifying respective terms of respective sample expressions that contradict corresponding respective disjunctive terms of respective sub-group k-CNF expressions; and

wherein determining which, if any, respective disjunctive terms of the boundary k-CNF to remove from the boundary k-CNF expression involves determining which respective disjunctive terms of the respective sub-group k-CNF expressions identified as contradictory to corresponding respective terms of sample expressions to remove.

7.   The method of claim 1 further including:

dividing the boundary k-CNF into multiple sub-group k-CNF expressions by separating respective terms that can express each other's feature information into different

sub-group k-CNF expressions such that such separation of terms does not result in loss of combinations of feature information due to such dividing;

wherein identifying respective terms of respective sample expressions that contradict corresponding respective disjunctive terms of the boundary k-CNF expression involves identifying respective terms of respective sample expressions that contradict corresponding respective disjunctive terms of respective sub-group k-CNF expressions; and

wherein determining which, if any, respective disjunctive terms of the boundary k-CNF to remove from the boundary k-CNF expression involves determining which respective disjunctive terms of the respective sub-group k-CNF expressions identified as contradicting corresponding respective terms of sample expressions to remove; and

dividing the boundary k-DNF expression into multiple sub-group k-DNF expressions by separating respective terms that can express each other's feature information into different sub-group k-DNF expressions such that such separation of terms does not result in loss of combinations of feature information due to such dividing;

wherein identifying respective terms of respective sample expressions that contradict corresponding respective conjunctive terms of the boundary k-DNF expression involves identifying respective terms of respective sample expressions that do not contradict corresponding respective conjunctive terms of respective sub-group k-DNF expressions; and

wherein determining which, if any, respective conjunctive terms of the boundary k-DNF to remove from the boundary k-DNF expression involves determining which respective conjunctive terms of the respective sub-group k-DNF expressions identified as not contradicting corresponding respective terms of sample expressions to remove.

8.   The method of claim 1,

wherein identifying respective terms of respective sample expressions that contradict corresponding respective disjunctive terms of the boundary k-CNF expression includes,

testing respective sample expression terms for contradiction with corresponding respective disjunctive terms of the boundary k-CNF expression in a prescribed order such that, for a respective given feature, a respective term representing higher resolution of such given respective feature is tested before a respective term representing a lower resolution of such given respective feature; and

not testing such respective term representing the lower resolution of such given respective feature if the testing of the respective term representing the higher resolution of such given respective feature indicates that there is a contradiction with the respective disjunctive term of the boundary k-CNF expression that corresponds to such respective term representing the higher resolution of such given respective feature.

9.   The method of claim 1,

wherein identifying respective terms of respective sample expressions that contradict corresponding respective disjunctive terms of the boundary k-CNF expression includes,

testing respective sample expression terms for contradiction with corresponding respective disjunctive terms of the boundary k-CNF expression in a prescribed order such that, for a respective given feature, a respective term representing higher resolution of such given respective feature is tested before a respective term representing a lower resolution of such given respective feature; and

not testing such respective term representing the lower resolution of such given respective feature if the testing of the respective term representing the higher resolution of such given respective feature indicates that there is a contradiction with the respective

disjunctive term of the boundary k-CNF expression that corresponds to such respective term representing the higher resolution of such given respective feature; and

wherein identifying respective terms of respective sample expressions that do not contradict corresponding respective conjunctive terms of the boundary k-DNF expression includes,

testing respective sample expression terms for contradiction with corresponding respective conjunctive terms of the boundary k-DNF expression in a prescribed order such that, for a respective given feature, a respective term representing higher resolution of such given respective feature is tested before a respective term representing a lower resolution of such given respective feature; and

not testing such respective term representing the lower resolution of such given respective feature if the testing of the respective term representing the higher resolution of such given respective feature indicates that there is a not a contradiction with the respective conjunctive term of the boundary k-DNF expression that corresponds to such respective term representing the higher resolution of such given respective feature.

10.   The method of claim 1,

wherein determining which, if any, respective disjunctive terms of the boundary k-CNF expression to remove includes,

determining which respective terms of the boundary k-CNF expression contradict corresponding respective terms of more than a prescribed number of sample expressions; and

wherein removing from the boundary k-CNF expression respective disjunctive terms determined to be removed includes,

removing from the boundary k-CNF expression respective disjunctive terms that contradict corresponding respective terms of more than the prescribed number of sample expressions.

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11. The method of claim 1,

wherein determining which, if any, respective disjunctive terms of the boundary k-CNF expression to remove includes,

determining which respective terms of the boundary k-CNF expression contradict corresponding respective terms of more than a prescribed number of sample expressions;

wherein removing from the boundary k-CNF expression respective disjunctive terms determined to be removed includes,

removing from the boundary k-CNF expression respective disjunctive terms that contradict corresponding respective terms of more than the prescribed number of sample expressions; and

wherein determining which, if any, respective conjunctive terms of the boundary k-DNF expression to remove includes,

determining which respective terms of the boundary k-DNF expression do not contradict corresponding respective terms of more than a prescribed number of sample expressions;

wherein removing from the boundary k-DNF expression respective conjunctive terms determined to be removed includes,

removing from the boundary k-DNF expression respective conjunctive terms that do not contradict corresponding respective terms of more than the prescribed number of sample expressions.

12. The method of claim 1,

wherein selecting multiple sample images from within the user query concept sample space includes,

selecting respective sample images that correspond to respective sample expressions that have a prescribed number of respective terms that contradict corresponding respective terms of the boundary k-CNF expression.

13. The method of claim 1,

wherein selecting multiple sample images from within the user query concept sample space includes,

selecting respective sample images that correspond to respective sample expressions that have a prescribed number of respective terms that contradict corresponding respective terms of the boundary k-CNF expression;

wherein the prescribed number is chosen by balancing a need for a prescribed number that is small enough that the selected sample images are likely to be indicated by the user as being close to the user's query concept with a need for a prescribed number that is large enough that the there is likely to be at least one set of multiple respective sample images that correspond to a set of multiple respective sample expressions that contradict the boundary k-CNF expression in the same term.

14. The method of claim 1,

wherein selecting multiple sample images from the user query concept sample space includes,

selecting respective sample images that correspond to respective sample expressions for which ψ terms in respective corresponding sample expressions contradict the boundary k-CNF expression;

wherein,

$\psi=1/ln(1/1-p)$, and

wherein p represents a probability that a given disjunctive term of the boundary k-CNF expression will be removed from the k-CNF expression in the step of removing

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from the boundary k-CNF expression respective disjunctive terms determined to be removed.

15.   The method of claim 1,

wherein selecting multiple sample images from the user query concept sample space includes,

selecting respective sample images that correspond to respective sample expressions that have a prescribed number of respective terms that contradict corresponding respective terms of the boundary k-CNF expression;

wherein the prescribed number is determined empirically by balancing a need for a prescribed number that is small enough that the selected sample images are likely to be indicated by the user as being close to the user's query concept with a need for a prescribed number that is large enough that the there is likely to be at least one set of multiple respective sample images that correspond to a set of multiple respective sample expressions that contradict the boundary k-CNF expression in the same term.

16.   The method of claim 1,

wherein defining the user query concept sample space includes,

selecting an initial set of sample images by choosing at least one sample image from each of multiple pre-clustered sets of sample images.

17.   The method of claim 1,

wherein selecting multiple sample images from within the user query concept sample space includes,

respectively selecting images that correspond to respective sample expressions that have a prescribed number of respective terms that contradict corresponding respective terms of the boundary k-CNF expression;

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wherein determining which, if any, respective disjunctive terms of the boundary k-CNF expression to remove includes,

determining which respective terms of the boundary k-CNF expression contradict corresponding respective terms of more than a prescribed number of sample expressions; and

wherein removing from the boundary k-CNF expression respective disjunctive terms determined to be removed includes,

removing from the boundary k-CNF expression respective disjunctive terms that contradict corresponding respective terms of more than the prescribed number of sample expressions.

18.   The method of claim 1,

wherein selecting multiple sample images from within the user query concept sample space includes,

respectively selecting images that correspond to respective sample expressions that have a prescribed number of respective terms that contradict corresponding respective terms of the boundary k-CNF expression;

wherein determining which, if any, respective disjunctive terms of the boundary k-CNF expression to remove includes,

determining which respective terms of the boundary k-CNF expression contradict corresponding respective terms of more than a prescribed number of sample expressions;

wherein removing from the boundary k-CNF expression respective disjunctive terms determined to be removed includes,

removing from the boundary k-CNF expression respective disjunctive terms that contradict corresponding respective terms of more than the prescribed number of sample expressions; and

wherein determining which, if any, respective conjunctive terms of the boundary k-DNF expression to remove includes,

determining which respective terms of the boundary k-DNF expression do not contradict corresponding respective terms of more than a prescribed number of sample expressions;

wherein removing from the boundary k-DNF expression respective conjunctive terms determined to be removed includes,

removing from the boundary k-DNF expression respective conjunctive terms that do not contradict corresponding respective terms of more than the prescribed number of sample expressions.

19.   A method of learning user query concept for searching visual images encoded in computer readable storage media comprising:

providing a multiplicity of respective sample images encoded in a computer readable medium;

providing a multiplicity of respective sample expressions encoded in computer readable medium that respectively correspond to respective sample images and in which respective terms of such respective sample expressions represent respective features of corresponding sample images;

defining a user query concept sample space by initially designating an initial set of sample images with at least one sample image from each of multiple pre-clustered sets of sample images as an initial user query concept sample space and by defining a boundary k-CNF expression and a boundary k-DNF expression which, together, encompass an initial set of sample expressions that correspond respectively to the sample images of the initial set of sample images; wherein the boundary k-CNF expression designates a more specific concept within the user query concept sample space; and

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wherein the boundary k-DNF expression designates a more general concept within the user query concept sample space;

refining the user query concept sample space by,

selecting multiple sample images from within the user query concept sample space that correspond to respective sample expressions that have a prescribed number of respective terms that contradict corresponding respective terms of the boundary k-CNF expression;

presenting the multiple selected sample images to the user;

soliciting user feedback as to which of the multiple presented sample images are close to the user's query concept;

wherein refining the user query concept sample space further includes, refining the boundary k-CNF expression by,

identifying respective terms of respective sample expressions that contradict corresponding respective disjunctive terms of the boundary k-CNF expression for those respective sample expressions corresponding to respective sample images indicated by the user as close to the user's query concept;

determining which, if any, respective disjunctive terms of the boundary k-CNF expression identified as contradicting corresponding respective terms of sample expressions indicated by the user as close to the user's query concept contradict corresponding respective terms of more than a prescribed number of sample expressions;

removing from the boundary k-CNF expression respective disjunctive terms that contradict corresponding respective terms of more than the prescribed number of sample expressions;

wherein refining the user query concept sample space further includes, refining the boundary k-DNF expression by,

identifying respective terms of respective sample expressions that do not contradict corresponding respective conjunctive terms of the boundary k-DNF expression

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for those respective sample expressions corresponding to respective sample images indicated by the user as not close to the user's query concept;

determining which, if any, respective conjunctive terms of the boundary k-DNF expression identified as not contradicting corresponding respective terms of sample expressions indicated by the user as not close to the user's query concept to remove from the boundary k-DNF expression;

removing from the boundary k-DNF expression respective conjunctive terms determined to be removed; and

repeating the steps involved in refining the user query concept sample space until the user ends search.

20.   The method of claim 19,

wherein determining which, if any, respective conjunctive terms of the boundary k-DNF expression to remove includes,

determining which respective terms of the boundary k-DNF expression do not contradict corresponding respective terms of more than a prescribed number of sample expressions;

wherein removing from the boundary k-DNF expression respective conjunctive terms determined to be removed includes,

removing from the boundary k-DNF expression respective conjunctive terms that do not contradict corresponding respective terms of more than the prescribed number of sample expressions.

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